Multidisciplinary Research For Sustainable Management Of Rural Watersheds: The River Njoro, Kenya (SUMAWA)

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Project Goals: 1) Research: Improve the understanding of biophysical and social dynamics governing watershed health in rural areas; 2) Development: Improve the health of threatened or degraded upland watershed systems in East Africa on a productive and sustainable basis, through management predicated on stakeholder participation and action supported by scientific information and analysis.

This proposed project originated through a strong and productive relationship between the PARIMA project and Egerton University in Kenya. Egerton University faculty approached the GL-CRSP Management Entity with an unsolicited proposal for a modest project in watershed studies. The ME, recognizing the need for a long-term watershed study involving livestock, land use, and wildlife issues, saw this as an opportunity to build local capacity by providing training in sciences related to watershed management and by engaging local communities in a critically important watershed in natural resource management. In conjunction with PARIMA and collaborating institutions from the Pond Dynamics/Aquaculture CRSP, an Assessment Team proposal was developed for problem model assessment and initial capacity building for the rehabilitation of the River Njoro watershed; the proposed research is an extension of that project.

Problem Model

The River Njoro is approximately 50 kilometers in length and its watershed covers about 200 square kilometers in southwest Kenya. Originating in the Eastern Mau Escarpment, the river flows through forests and grazing and agricultural lands before serving the towns of Njoro and Nakuru; it eventually empties into Lake Nakuru National Park.

Over the years, high population growth and accompanying land fragmentation have placed high demands on the resources of the River Njoro watershed, thereby upsetting environmental stability (Karanja et al. 1989). There has been serious degradation of the ecological integrity and hydrologic processes within the watershed (Chemilil 1985, Bretschko 1995, Mathooko 2001 Shivoga 2001), as indicated by loss of biodiversity,

Table 3: Multidisciplinary Research for Sustainable Management of Rural Watersheds: The River Njoro, Kenya (SUMAWA), Activities Matrix.

SUMAWA addresses the following USAID Field Strategic Objectives:

USAID/REDSO/ESA S.O. 5. Enhanced African capacity to achieve regional food security.
USAID/Kenya S.O. 5. Improved natural resources management in targeted biodiverse areas by and for the stakeholders.
USAID/Kenya S.O. 7. Increased rural household incomes.

Activities	Research Outputs	Developmental Impacts	IEHA/USAID AgSS Themes
1. Build stakeholder capacity to analyze watershed issues, implement solutions, develop a participatory action process, conduct socio-economic analysis and establish communication for dissemination of results.	Adoptive research outcomes generated and disseminated. Stakeholder institutions developed; capacity to leverage resources enhanced. Socio-economic status and impacts, agricultural practices, watershed perceptions, problems, and priorities, and livelihood coping strategies evaluated. Constraints and opportunities to improving rural livelihoods, agricultural productivity, and impacts on WS analyzed. Policy-relevant project results documented and disseminated.	Tools developed by the project will make it possible to better define variation outside of the "natural" system and recognize "unhealthy" states of aquatic and terrestrial ecosystems. SUMAWA will help determine how rehabilitation should be prioritized, considering costs and local and regional goals and conditions. It will be possible to assess the relative costs of policies and communicate this information to stakeholders to help them decide on the preferred rehabilitation strategy. The proposed EACWAM will be built in coordination with the research and outreach programs that are called for by SUMAWA. A capacity development program will be implemented such that when the project is concluded, the regional partners will be internationally recognized in watershed studies, spatial analysis and stakeholder participation services. EACWAM will serve as an established repository for scientific information. The Njoro watershed will be established as a long-term watershed research site for watershed hydrology, ecological study, and socio-economic analysis, with an emphasis on long-term sustainability of agricultural and livestock practices. SUMAWA will establish a process for linking stakeholder participation with watershed research that may be transferred to other areas in Kenya and East Africa.	**Theme 3 USAID/AgSS:** Bridging the knowledge divide through training, outreach and research. **Theme 3. IEHA:** Developing human capital, infrastructure and institutions. **Theme 4. USAID/AgSS:** Sustainable agriculture and sound environmental management. **Theme 4. IEHA:** Environmental management for agriculture and rural sector growth. **Theme 5. IEHA:** Community and producer based organizations contribute to agricultural growth. **Theme 6. IEHA:** Integrate vulnerable groups and transitional countries in the development processes.
2. Create a set of geospatially-referenced databases and models that enhance the capacity of the stakeholders to make decision regarding their activities within the watershed and establish demonstrations for technology transfer to the communities.	East African Center for Watershed Assessment & Management (EACWAM) capacity development program implemented. Sustainable grazing and farming practices that improve productivity and watershed conditions identified, assessed, demonstrated, and tested. Adoptive research and policy analysis outcomes generated and disseminated. WS monitoring, evaluation, and outreach program established. Decision support packages created and accepted for use in research, management, and development communities.		**Theme 1. USAID/AgSS:** Scientific and technological applications harnessed. **Theme 1. IEHA:** Mobilize science, technology and build capacity. **Theme 2. USAID/AgSS:** Trade opportunities and improving capacity of farmers to participate. **Theme 2. IEHA:** Agricultural trade and market systems. **Theme 3 USAID/AgSS:** Bridging the knowledge divide through training, outreach and research. **Theme 3. IEHA:** Developing human capital, infrastructure and institutions. **Theme 4. USAID/AgSS:** Sustainable agriculture and sound environmental management. **Theme 4. IEHA:** Environmental management for agriculture and rural sector growth.
3. Address human health issues within the watershed through the analysis of waterflow and disease patterns.	Participatory and scientific assessment of human health trends, their relationship to current and future domestic water quantity and quality, wastewater, and sanitation conditions completed. Participatory assessment, testing, and demonstration of promising improvements in domestic water supply and sanitation of rural households completed. Community Action Plans developed to improve domestic conditions in select sites.		**Theme 1. USAID/AgSS:** Scientific and technological applications harnessed. **Theme 1. IEHA:** Mobilize science, technology and build capacity. **Theme 2. USAID/AgSS:** Trade opportunities and improving capacity of farmers to participate. **Theme 2. IEHA:** Agricultural trade and market systems. **Theme 3 USAID/AgSS:** Bridging the knowledge divide through training, outreach and research. **Theme 3. IEHA:** Developing human capital, infrastructure and institutions.
4. Conduct a regional analysis to determine applicability of results from Njoro for regional application and build African capacity for regional scale analysis.	High quality GIS and RS database established for regional spatial analysis. Analysis of the potential for applications of research findings in East and Central Africa completed. Institutional capacity at Egerton University for advanced WS analysis enhanced.		**Theme 1. USAID/AgSS:** Scientific and technological applications harnessed. **Theme 1. IEHA:** Mobilize science, technology and build capacity. **Theme 3 USAID/AgSS:** Bridging the knowledge divide through training, outreach and research. **Theme 3. IEHA:** Developing human capital, infrastructure and institutions. **Theme 4. USAID/AgSS:** Sustainable agriculture and sound environmental management. **Theme 4. IEHA:** Environmental management for agriculture and rural sector growth.

degraded habitats, and disruption of the hydrologic processes (i.e., infiltration and percolation, runoff and interception of raindrops). These changes have in turn contributed to increased pollution levels, declining productivity of natural resources, and loss of watershed services. Related impacts include declining livelihoods of human inhabitants, as well as decreased access to resources for their livestock. The deterioration of the watershed has led to ever increasing threats to Lake Nakuru and the surrounding National Park, which, through tourism, is a major income-generating resource.

The proposed project is a multidisciplinary research effort focusing on the biophysical and human-related factors governing processes in the River Njoro watershed. The focus is on the upland portion of the watershed, where livestock and smallholder agriculture are significant components affecting the ecological and economic health of the watershed system. Interventions and outreach within the River Njoro watershed will be developed through the integration of scientific research findings with stakeholder analyses to support local communities and decision makers in effectively identifying and implementing local solutions to enhance both the biophysical and human-related components of the watershed.

Project Description

The proposed SUMAWA project is the first step in creating an interdisciplinary watershed rehabilitation model through technical, social, and policy interventions that will lead to the restoration of the health of the River Njoro watershed; the ultimate goal is to improve the long-term sustainability of rural watersheds throughout Kenya and East Africa.

There have been several efforts made to assess the quality and quantity of water in the River Njoro watershed (Vareschi 1982, Kairu 1994, Leichtfried and Shivoga 1995, Bretschko 1996, Shivoga 2001), but the methods were expensive, sophisticated, and non-participatory and could not be sustained. Basic ecological findings have not been translated into a tool that can be used by the public, conservationists, planners, and policy makers to mitigate environmental degradation in the watershed, nor has the information been made available to the public. Moreover, little attention has been paid to the livestock sector (an important economic component of the watershed) with respect to both beneficial and adverse effects of grazing practices. These critical knowledge gaps will be addressed in the proposed research. The definition of "rehabilitation" of the watershed will be determined by societal goals for aquatic and terrestrial ecosystem management that will focus on the concepts of watershed "health" and sustainability. The determination of the desired future state of the watershed requires input from a broad range of stakeholders in public meetings, workshops, and outreach activities.

The proposed research project will, through the development of an integrated

watershed model, test the impacts of specific human settlement patterns on the health of the ecosystems in the watershed and show their linkages to the health and livelihood security of stakeholders and residents. Spatial pattern influences on hydrologic and nutrient processes will be tested through scenarios of land pattern change. The model will permit an evaluation of the direct effects of land use change through human actions and the indirect effects through ecological change (Miller et al 2002a, Miller et al. 2002b). Integral to this approach will be a livestock sector model that will allow researchers and land managers to infer beneficial (economic or ecological) and negative (non-point source pollution and downstream effects) impacts of various grazing practices (Guertin et al. 2000).

Prototype approaches will be developed with data collected over the course of the three-year project; these approaches will be reviewed, tested, and demonstrated to stakeholders. Methods will be developed for assessing the health and performance of watershed ecosystems: pastoral, urban, agricultural, and "natural" components of landscapes, as well as the entire landscape (Mageau et al. 1995). Identified watershed health indicators will be discussed with stakeholders in workshops and public meetings to assess their usefulness for defining ecosystem health and for setting rehabilitation priorities.

Little is known about the quantitative influence of specific management and policy options on the evolution of landscapes and the health of ecosystems. It is hypothesized that in the River Njoro watershed, the economic model to be developed can provide information about human responses to policy change. This is based on the assumption that the variables used to predict the values in residential and alternative uses are functions of ecological features, human infrastructure, and land use policies.

The research team is divided into four research component teams with dedicated foci relating to the broad topics that will drive research over the life of the project: stakeholder involvement; ecology; socio-economics; and watershed hydrology.

Stakeholder Involvement. The participation and empowerment of all River Njoro stakeholders is an integral part of the SUMAWA project. The focus of this process will be on improving stakeholders' understanding of the full range of options between the end points of catastrophic human-induced system degradation and the system's "natural state." The project will also increase stakeholders' representation in decision making. The four research teams will work with stakeholders in all of the communities in the River Njoro watershed to ensure that appropriate technologies and interventions not only have technical and scientific merit, but also are welcomed and will be utilized by the members of the communities.

Development of Watershed Health Indicators. Methods will be developed and tested to assess the health of ecosystems in the River Njoro watershed. The project will quantify the general characteristics of all living systems at all scales that are generally associated with "well-functioning," including vigor, organization, and resilience (Costanza et al. 1992, Mageau et al. 1995). These characteristics can be applied with equal facility to "natural" ecosystems, agroecosystems (including small-scale agriculture and grazing practices in the upper watershed), and urban/suburban ecosystems. Measures will relate to the aggregate productivity of the landscape, its organization (as measured with various spatial pattern indices), and its resilience (as measured by dynamic landscape models). The model's dynamic, spatially distributed nature will allow the researchers to develop indicators of watershed health. GIS analysis will be used to coordinate field research from all four research teams and remotely sensed data to provide a coherent understanding of the spatial distribution of land cover, land use, and watershed health. Using hydrologic components, indicators will be developed to assess impacts to stream flow from land development. Changes in stream baseflow and in peak storm magnitudes will be used to evaluate hydrologic impacts from development (Miller et al. 2002b).

Indicators of ecosystem health will also be developed through model predictions in combination with spatial pattern indices (descriptive statistics used to quantify landscape patterns) to reflect the ability of the landscape to support certain ecosystem functions. The effects of land cover and land use changes are scale dependent; recovery or resilience can be represented by considering source population distance and natural corridors (represented by various indices), which influence recovery rates of both plants and animals following catastrophic events (Detenbeck et al. 1992, Gustafson and Gardner 1996, Hawkins et al 1988, Shivoga 2001).

The SUMAWA project will also develop a community-based Biological Monitoring and Assessment Tool (BIOMAT) for the River Njoro watershed; this tool will assess water pollution through its effect on living organisms. The BIOMAT must be cost-effective, yet scientifically valid and environmentally benign. It must be able to provide for multiple site investigations in a field season. And it must allow for the rapid collection, compilation, analysis, and interpretation of environmental data to facilitate management decisions and resultant actions for control and/or mitigation of impairment.

Development of a Multi-Criteria Decision Support Tool. A multi-criteria decision support tool (MCDST) will be developed to provide a method for the users of the watershed to express values and choices and participate in the decision making process. Implementation of the MCDST will focus on the selection of appropriate indicators given the dominant uses of the watershed, and on the evaluation of indicators in terms of the degree of change that is acceptable to watershed users. The MCDST utilizes a process for

identifying a problem, defining alternative actions, defining criteria upon which to judge those actions, and analyzing the alternatives for the best solution. The MCDST supports the decision making process by providing a framework that can compare the relative impacts of alternative actions using a wide array of criteria. Criteria can be measured in a combination of quantitative and qualitative units, including – but not limited to – monetary cost-benefit analysis and off-site impacts associated with changing watershed conditions. All decisions will ultimately require, however, that the changes be judged according to their relative impacts.

The project will develop an automated system for hydrologic assessment using distributed hydrologic modeling in a GIS framework. Results from this tool will be incorporated into the MCDST and used to visualize the effects of various land uses on watershed hydrology and demonstrate hydrologic response. By doing so, the research team will provide guidance and information in the form of simple metrics and measurements to empower local communities in sustainable watershed management. The development of process-response models will assist in scenario development and decision making in planning and watershed management.

One advantage of the proposed MCDST is its ability to incorporate a range of criteria that are selected and weighted by both research scientists and watershed stakeholders. Various points of view and levels of uncertainty can be incorporated into the analysis. Alternative actions can be considered from different points of view; the optimal action may become clear when one option scores highly from all or most points of view.

Tiered Workshop Process. The SUMAWA project will employ tiered workshops from the grassroots to the district level; the process will attempt to develop and extend "common ground." Face-to-face workshops will be small (about 40 participants, three-day events designed to involve a range of stakeholders in the process. They will focus on building consensus around: 1) ecosystem health; 2) the criteria and their relative weights in the MCDST; 3) the preferred state of the overall watershed; and 4) the sites of the watershed that should be rehabilitated to reverse the decline in water quantity and quality.

Location-Based Watershed Public Meetings. The project intends to fully exploit the traditional public meetings (*barasas*) of stakeholders throughout the watershed. These meetings will provide an opportunity for open discussion and feedback between the researchers and the stakeholders. They will also be used to present research findings to the stakeholders in a setting that will permit collective decision making as an extension of consensus-building workshops.

Establishment of Experimental and Demonstration Sites for Technology Transfer.

Based on the expertise of the research team, socioeconomic assessments, and stakeholders' preferences, a number of experimental and demonstration sites will be established at Egerton University and Lake Nakuru National Park to facilitate technology transfer to the stakeholders. The technologies that will be used to demonstrate land use alternatives include integrated livestock-fish farming, butterfly farming, and beekeeping.

Human Health, Water Supply, and Sanitation In Sustainable Watershed Management. Many poor households in the River Njoro watershed rely on direct use of river water for drinking, domestic use, and livestock. The result is a high risk of exposure to human and animal pathogens, substantial distances to transport inadequate quantities of water to the home, and intensive human and livestock disturbances to sections of the river (Mathooko 2001). This component of the project will examine existing and recent trends in human health, water supply, and sanitation conditions of poor households in the upper and middle portions of the watershed to support the development of sustainable, decentralized community-based options for improvements.

The objectives are to: 1) assess, from multiple perspectives, the relationship between human health and the productivity of upland/rural communities on the one hand, and water supply and sanitation conditions on the other; 2) increase understanding of the linkages between human health, rural productivity, and sustainable improvements in household water supply and sanitation, and study the implications for sustainable watershed management through focused, integrated research on the River Njoro watershed; and 3) develop expertise at Egerton University to identify and support sustainable, decentralized improvements in community water supply and sanitation that address the priorities of the residents of the watershed.

The first step will be to collect data on water-related infectious diseases, HIV/AIDS, and other relevant health indicator statistics from clinics and hospitals in the watershed, and to analyze this information using basic epidemiological methods (Feachem et al. 1977, Hennekens and Buring 1987). Intensive household-level case studies will be carried out in two to four communities in the upper and middle watershed, using a variety of in-depth qualitative, structured observation, and quantitative methods, along with participatory assessment methods; the case studies will examine stakeholders' perceptions and practices concerning water supply, water use, health and disease, and sanitation conditions. Indicator data on household health status, water supply, and sanitation practices will be integrated with watershed characterization data into a GIS framework; spatial epidemiological analysis methods will be applied to identify disease patterns and critical areas for investigation (Cliff and Ord 1981, Bailey and Gartrell 1995). The results of these investigations, as well as implications and options, will be discussed with affected communities and disseminated to other stakeholders and decision makers in the watershed.

Finally, based on the initial results of the public meetings, two to three communities will be selected for the testing of decentralized, alternative approaches to household water security and safer sanitation in the context of sustainable watershed management. Such approaches include: 1) off-site community watering facilities for livestock; 2) household rainwater rooftop harvesting for domestic use; 3) improvements to open wells and boreholes; 4) point of use disinfection; 5) low volume pour-flush toilets; etc.

Regional Assessments and Spatial Analysis. Water resource issues are of critical importance to human and ecological welfare. People in ecologically sensitive areas are at risk due to the responsiveness of their environment to negative impacts. In the East and Central African region, which is highly sensitive to change, human pressures and adverse conditions have significantly altered the environment over the past several decades.

One of the long-term goals of the SUMAWA project is to develop regional expertise in watershed analysis for the sustainable management of watersheds. The River Njoro watershed was chosen as the study site for this project because its biophysical and socio-economic characteristics are such that interventions and solutions developed there will have broad applications throughout Kenya and other parts of East and Central Africa.

The project's geographic information system (GIS) will be expanded and utilized in conjunction with remote sensing data to place the Njoro watershed in a regional context and identify potential areas where the results from the Njoro research may be applied. At the same time, the project will help to establish the skill base in rural East and Central Africa for complex watershed analyses and will support long-term sustainable management through the improved use of scientific tools.

The main objectives of this component of the project are to: 1) enhance the GIS and spatial analysis capabilities and databases at Egerton University; 2) relate biophysical and human-related indices discovered within the Njoro watershed to the conditions and processes governing watershed conditions throughout the region; and 3) identify potential study areas for the application of interventions and research concepts developed in the River Njoro watershed.

Capacity Building

The SUMAWA project's emphasis on stakeholder participation in tiered workshops and public meetings (*barasas)* will build the capacity of community members and policy makers to make informed decisions, based on scientific findings and information, about the design of an effective rehabilitation strategy, including appropriate technologies and interventions, in order to improve the ecological health of the watershed.

The project will support a large number of students, reflecting the overall commitment

of team members to improve human capacity in Kenya for integrated watershed analysis. The majority of the student training will take place at Egerton and Moi Universities; nine qualified students will be trained to utilize their skills for watershed assessment and integrated research in the region. One Kenyan graduate student will be trained in the United States in GIS and landscape analysis, working under the guidance of Dr. Scott Miller in the Department of Natural Resources at the University of Wyoming and the Wyoming Geographic Information Science Center (WYGISC). The goal is to generate a large number of skilled practitioners who are dedicated to solving watershed management issues in rural East and Central Africa in a sustainable manner. Integral to the project's success, both in terms of short-term research and development goals and long-term regional impact, is the establishment of an East African Center for Watershed Assessment and Management.

The long-term goal of the project is to generate a conceptual model of watershed processes, through a synthesis of the project team's findings, that will aid in local and regional decision making. By adopting methods that allow for stakeholder involvement and capacity building through hydrologic, ecological, and sociological approaches, the project hopes to enhance the sustainability of the River Njoro watershed and provide a working model for rural watersheds in East and Central Africa.

Research Team and Institutional Linkages

A multidisciplinary research team composed of experts in socio-economics, watershed hydrology, ecology, and stakeholder involvement has been assembled for this project. The research team has been subdivided into these four research component teams with dedicated foci relating to the broad topics that will drive research over the life of the project. These components will work as quasi-independent entities with their own team leaders, but research findings and the direction of future research will be determined through cross-fertilization among these component teams.

Leading the research effort as Principal Investigator is Dr. Scott Miller, a professor in the Department of Renewable Resources at the University of Wyoming. The Co-Principal Investigator, Marion Jenkins, is an Assistant Research Engineer with the Civil and Environmental Engineering Department at the University of California, Davis.

The host country team is headed by Dr. William Shivoga, who was instrumental in bringing the project to the attention of the GL-CRSP. Dr. Shivoga is chair of the Department of Environmental Sciences at Egerton University and is an ecologist/ limnologist and biodiversity conservationist. Dr. Francis Lelo, Dean of the Faculty of Environmental Science and Natural Resources, Egerton University will lead the stakeholder involvement research team. Dr. Lelo is a renowned specialist in PRA/PAPPA Community and Stakeholder mobilization. Dr. Mucai Muchiri, head of the Department of Fisheries, will

lead the ecology research team. Dr. Muchiri has co-ordinated a Pond Dynamics/ Aquaculture CRSP training project on pond construction and aquaculture management for Kenya fisheries extension workers. Dr. Charles Maina-Gichaba, chair of the Department of Geography at Egerton University, will lead the watershed characterization research team. Dr. Gichaba is a specialist in the use of GIS in water resources management.

Altogether, scientists and managers from three US educational institutions (Univ. of Wyoming, UC Davis, and Utah State), two Kenyan Universities (Egerton and Moi) and two Kenyan government institutions (Department of Fisheries and the Kenya Wildlife Service) serve as project managers and team members. Institutional linkages have been established with the Kenya Wildlife Service and the Kenya Fisheries Department, as well as with Egerton and Moi Universities. The project intends to develop collaborative relationships with the Network for Water and Sanitation (NETWAS) and other national and international NGOs involved in water supply and sanitation in Kenya.

To support the research into human health, water supply, and sanitation, the project will use Dr. Jenkins's existing contacts (through her research projects in environmental public health engineering and sanitation in Africa) to form linkages with NETWAS (Network for Water and Sanitation, an East African regional center of training and expertise based in Nairobi) and other national and international NGOs involved in water supply and sanitation in Kenya. This research component will be guided by Dr. Lois Chiuri and Dr. Jenkins, and integrate a member of the district public health staff into the socio-economic research team at Egerton University. Dr. Chiuri is a Senior Lecturer and specialist in Gender, Development and Environment issues at Egerton University. Research within this module will be performed by two Kenyan graduate students located at Egerton University.

Dissemination Plan

The dissemination of research results on a regular basis to stakeholders and the involvement of stakeholders in decision making are integral aspects of the SUMAWA project. Traditional public meetings throughout the watershed will provide an opportunity for open discussion and feedback between the researchers and the stakeholders. Techniques for transforming data into forms that are useful and understandable to the stakeholders will be employed, including translating materials into local languages and creatively using tools like GIS. Workshops at the grassroots, divisional, and district levels also provide opportunities to disseminate research results to and build consensus among local government officials and other stakeholders.

The multi-criteria decision support tool (MCDST) is a flexible tool that will be used to compare the relative impacts on ecosystems and economic systems of various development scenarios. Impacts will be displayed spatially when suitable, and the results will be

communicated to a wide range of stakeholders via workshops, publications, and public meetings.

Developmental Relevance and Anticipated Impacts

The project component that focuses on improving water supply and sanitation in the context of sustainable watershed management will have a direct impact on human health in communities where decentralized, participatory approaches to address these problems are tested. The process could serve as a model for the integration of interventions related to basic drinking water needs, rural water supply, and sanitation into the rehabilitation of other watersheds in East Africa and beyond.

The output of the watershed models to be developed will be used directly or in combination with empirical relationships to create indicators with which to judge watershed function and overall health. By comparing current vulnerability to past variability in the health of the River Njoro watershed, it will be possible to better define variation outside of the "natural" system and recognize "unhealthy" states of aquatic and terrestrial ecosystems. The SUMAWA project will help determine how rehabilitation efforts should be prioritized, considering local and regional goals and conditions; it will consider such issues as the complex interplay of spatial and temporal influences that mitigate or exacerbate human activities. The project will assess the costs of rehabilitation and techniques within the regional landscape to maximize cost-effectiveness. It will be possible to assess the relative costs of policies and communicate this information to stakeholders to help them decide on the preferred rehabilitation strategy.

A goal of the SUMAWA project is to develop a regional center of excellence in integrated watershed studies. The proposed East African Center for Watershed Assessment & Management (EACWAM) will be built in coordination with the research and outreach programs that are called for by the project's components. A capacity development program will be implemented such that when the project is concluded, the regional partners will be internationally recognized in watershed studies, spatial analysis and stakeholder participation services. EACWAM will serve as an established repository for scientific information, with significant data sets and expertise useful to scientists interested in East Africa. The Njoro watershed will be established as a long-term watershed research site for watershed hydrology, ecological study, and socio-economic analysis, with an emphasis on long-term sustainability of agricultural and livestock practices. Monitoring programs will be established in watershed hydrology, ecology, stakeholder involvement, and socio-economics, and will be designed to outlive the project. Long-term monitoring by the experimental watershed station will serve as a vital and continuing effort in validating the conclusions and recommendations generated by the proposed research. A technology

and knowledge transfer program will be initiated. This program is designed to operate at several levels: state-of-the-art scientific knowledge and methods will be implemented in the experimental research and design of the long-term monitoring program, while a stakeholder outreach and participation program will serve to link the research approach with community needs and participation. A goal of this project is to establish a successful process for linking stakeholder participation with watershed research that may be transferred to other areas in Kenya and East Africa. This project will serve as a model for integrated and long-term watershed study, capacity building, and technology/knowledge transfer that will enhance the establishment of EACWAM as a regional center of excellence.

Benefits to the United States

This project is intended to establish an improved process for integrating scientific research with stakeholder participation and outreach. A common problem in research studies is the breakdown between academic findings and application; often technology or knowledge transfer is attempted upon project completion and is not well targeted, and hence under-utilized. The SUMAWA project intends to develop a system for integrated research and outreach that can be extended to the United States and that can lead to enhanced application of research findings for societal benefit. The different mechanisms by which stakeholder-driven decision making is successfully implemented in the formulation of community-based watershed action plans for sustainable development in the United States and Kenya will be investigated, and recommendations for improved implementation will be formulated.

Another outcome of the SUMAWA project will be a long-term partnership for international cooperation in watershed research between the United States and Kenya. The Njoro watershed is a unique outdoor semi-arid research laboratory, and the local partners (Egerton and Moi Universities, and the Kenya Wildlife Service and Fisheries Department) are willing and capable partners for conducting research in integrated sustainable watershed management. These partnerships will provide opportunities for graduate and undergraduate student learning in cooperation with universities in the United States. Improved research and teaching tools for the sustainable management of at-risk watersheds in developing nations will augment student appreciation for critical international development issues.

New scientific technologies, including remote sensing and geographic information systems, will be developed. These technologies are specifically targeted to aid in visualization, problem identification, and decision support for land managers and decision makers, including small landholders. The calibration and application of these models will make them of immediate benefit to the research area in Kenya, but they are designed to be highly modular and easily modified, and therefore portable and applicable within the United States.